U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-275 003

Sulfate Testing of Four Vehicles

Olson Labs, Inc, Anaheim, Calif

Prepared for

Environmental Protection Agency, Ann Arbor, Mich

Oct 76

PB 275 003

EPA-460/3-76-023

October 1976

SULFATE TESTING OF FOUR VEHICLES

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-460/3-76-023		

4. TITLE AND SUBTITLE	5. REPORT DATE
Sulfate Testing of Four Vehicles	October 1976
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Robert J. Herling	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Olson Laboratories, Inc. 421 East Cerritos Avenue Anaheim, CAlifornia 92805	11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Environmental Protection Agency Motor Vehicle Emission Laboratory 2565 Plymouth Rd. Ann Arbor, Michigan 48105	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

As part of the Environmental Protection Agency's program to characterize particulate emissions and quantify sulfuric acid emissions from catalyst and noncatalyst vehicles, 75 vehicles were to be tested in a baseline study. These vehicles included production vehicles, preproduction prototypes and advanced engine concepts. As part of this baseline study, Olson Laboratories, Inc., has tested four vehicles. The procedures used to condition and test these vehicles are detailed in this report, and the results are presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sulfate Sulfuric Acid Catalytic Converters		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
	Unclassified	34
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	PC A03 / MF A01

EPA Form 2220-1 (9-73)

EPA-460/3-76-023

SULFATE TESTING OF FOUR VEHICLES

by

Robert J. Herling

Olson Laboratories, Inc.
421 East Cerritos Avenue
Anaheim, California 92805

Contract No. 68-03-0452
Task No. 7

EPA Project Officer: Joseph H. Somers

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

October 1976

1a.

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Olson Laboratories, Inc., Anaheim, California 92805, in fulfillment of Contract No. 68-03-0452, Task No. 7. The contents of this report are reproduced herein as received from Olson Laboratories, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-76-023

TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION.	1
2.0	VEHICLES.	1
3.0	VEHICLE PROCONDITIONING PROCEDURES. . . .	3
3.1	Test Fuel	3
3.2	Vehicle Preparation	9
3.3	Mileage Accumulation.	9
4.0	EMISSION TESTING PROCEDURES	10
4.1	Driving Cycles.	10
4.2	Gaseous Emissions Measurements.	12
	Hydrocarbon Measurement	12
	Carbon Monoxide Measurement	12
	Carbon Dioxide Measurement.	13
	Oxide of Nitrogen Measurement	13
4.3	Particulate/Sulfate Emissions Measurements.	13
5.0	TEST RESULTS.	17

LIST OF ILLUSTRATIONS

Figure		Page
1	Dilution Tunnel	14
2	Particulate Sampling System	16

LIST OF TABLES

Table		Page
1	Vehicle Log - 1976 VW Dasher.	3
2	Vehicle Log - 1976 Matador S/N A6A857H217338	4
3	Vehicle Log - 1976 Cadillac S/N 6D47S6Q126956	5
4	Vehicle Log - Skylark S/N 4B27C6L100811	6
5	Certificate of Analysis	7

LIST OF TABLES (CONT'D)

Table		Page
6	Fuel Analysis	8
7	Key Mode Tests.	9
8	Santiago Canyon Road Route.	11
9	Comparative SO_4 Analysis.	18
10	Special Test Results.	19
11	Special Test Results.	21
12	Special Test Results.	23
13	Special Test Results.	25
14	Comparative SO_4 Results	27

1.0 INTRODUCTION

As part of the Environmental Protection Agency's program to characterize particulate emissions and quantify sulfuric acid emissions from catalyst and noncatalyst vehicles, 75 vehicles were to be tested in a baseline study. These vehicles included production vehicles, preproduction prototypes and advanced engine concepts. As part of this baseline study, Olson Laboratories, Inc., has tested four vehicles. The procedures used to condition and test these vehicles are detailed in this report, and the results are presented.

2.0 VEHICLES

Four vehicles were identified for testing. These vehicles are 1976 models, certified in California. The four vehicles were:

1. 1976 Volkswagen Dasher - S/N 3262045233, 4-cylinder, fuel injection no air pump, monolith catalyst

   Source: Volkswagen of America

2. 1976 AMC Matador - S/N AGA857H217338, V8, 304 CID engine with 2-barrel carburetor and air pump, pelleted catalyst

   Source: National Car Rental

3. 1976 Cadillac Coupe de Ville - S/N 6D47S6Q126956, V8, 500 CID engine with 4-barrel carburetor and air pump, pelleted catalyst

   Source: Dollar Rent-a-Car

4. 1976 Buick Skylark - S/N 4B27C6L100811, V6, 231 CID engine with 2-barrel carburetor and no air pump, pelleted catalyst

Source: Olson Laboratories, Inc.

Attempts were made to select vehicles which had been driven between 1,000 and 5,000 miles prior to the initiation of mileage accumulation. Vehicle logs detailing the preconditioning and testing history of each car are included as Tables 1 through 4.

3.0 VEHICLE PRECONDITONING PROCEDURES

3.1 TEST FUEL

Seven barrels of Amoco Indolene HO Clear were prepared as the test fuel. The batch analysis of the fuel provided by Amoco is shown in Table 5. Thiophene was added to each barrel to increase the sulfur content of the test fuel to approximately 300 ppm. After mixing, fuel samples from each of the seven barrels were submitted to the Union Oil Research Center for analysis. The results of the analyses are listed in Table 6. Variations in the Reid Vapor Pressure and distillation characteristics are a result of fuel storage, sample handling, and sample analysis effects.

Analytical procedures used by Union Oil are listed below:

o	Lead	ASTM	D 3237
o	Sulfur	ASTM	D 2622
o	Reid Vapor Pressure	ASTM	D 323
o	API Gravity	ASTM	D 287
o	Distillation	ASTM	D 86

Table 1. VEHICLE LOG - 1976 VW DASHER

DATE	MILEAGE Start	MILEAGE End	FUEL	ACTIVITY - COMMENTS
2/2/76	520	600	Tank	Pick car up from VW
2/3/76	600	660	Tank	Road route prep
2/4/76	660	731	Tank	Road route prep, vehicle prep - car had high idle CO, contacted VW. VW specified additional tests
2/5/76	731	731	Tank	Disconnected canister and crankcase vent CO @ idle 1.4%; schedule vehicle maintenance by VW
2/6/76	731	843	Tank	Serviced by VW - found 2 fuel injectors disconnected. Vehicle repaired; idle CO adjusted to 0.05%; test fuel added
2/9/76	843	1000	S-1	Road route
2/10/76	1000	1188	S-1	Road route
2/11/76	1188	1350	S-2	Road route
2/13/76			S-2	Tank filled; car moved into soak area
2/15/76	1350	1358	S-2	LA-4 preconditioning
2/16/76	1358	1435	S-2	SO_4 Sequence (1st test)
2/17/76	1435	1512	S-2	SO_4 Sequence - retest

Table 2. VEHICLE LOG - 1976 MATADOR S/N A6A857H217338

DATE	MILEAGE Start	MILEAGE End	FUEL	ACTIVITY - COMMENTS
2/4/76	1380	1403	Tank	Car picked up from National and tuned to spec
2/5/76	1403	1403	S-1	Car fueled and key mode run
2/9/76	1403	1516	S-1	Start road route
2/10/76	1516	1752	S-1	Road route
2/11/76	1752	1969	S-2	Road route
2/12/76	1969	2103	S-2	Road route
2/16/76	2103	2320	S-3	Road route
2/17/76	2320	2417	S-3	Road route
2/17/76	2417	2426	S-3	LA-4
2/18/76	2426	2502	S-3	SO_4 Sequence (1st test)
2/19/76	2502	2578	S-3	SO_4 Sequence (retest)
2/20/76				Car returned to National

Table 3. VEHICLE LOG - 1976 CADILLAC S/N 6D47S6Q126956

DATE	MILEAGE Start	MILEAGE End	FUEL	ACTIVITY - COMMENTS
2/17/76	8016			Car received and tuned
2/18/76	8017	8290	S-3	Start road route
2/19/76	8290	8474	S-4	Road route
2/20/76	8474	8622	S-4	Road route
2/23/76	8622	8848	S-5	Road route
2/24/76	8848	9017	S-5	Road route
2/24/76	9017	9025	S-5	LA-4
2/25/76	9025	9104	S-5	SO_4 Sequence (1st test)
2/26/76	9104	9183	S-5	SO_4 Sequence (retest)

Table 4. VEHICLE LOG - SKYLARK S/N 4B27C6L100811

DATE	MILEAGE Start	MILEAGE End	FUEL	ACTIVITY - COMMENTS
2/24/76				Vehicle was tuned by dealer to mfg spec
2/25/76	1207.8	1344.4	S5 & S6	Road route
2/26/76	1344.4	1568.6	S-6	Road route
2/27/76	1568.6	1708.6	S-6	Road route
3/1/76	1708.6	1920.0	S-6	Road route
3/2/76	1920.0	2117.3	S-6	Road route
3/3/76	2117.3	2218.7	S6 & S7	Road route
3/3/76	2218	-	S-7	LA-4 preconditioning
3/4/76				Mass bench breakdown prior to test
3/3/76	2221	2229	S-7	LA-4
3/8/76	2229	2312	S-7	SO_4 Sequence - severe fuel system overheat
3/9/76	2312	2390	S-7	SO_4 Sequence (retest)
3/10/76	2390	2468	S-7	SO_4 Sequence (retest)

P.O. Box 710
Whiting, Indiana 46394

LABORATORY SERVICES DIVISON

Table 5. CERTIFICATE OF ANALYSIS

CONSIGNEE: Standard Oil Division
Amoco Oil Company
205 Marion
Attn: Mr. J.O. Logelin
River Rouge, Michigan 48218

PRODUCT: Indolene Motor Fuel HO III
TANK NO: After Batch 5R
DATE ISSUED: 10-24-75

TEST	ASTM METHOD	PRODUCT ANALYSIS SPECIFICATION CONTROL LIMIT	SAMPLE D13483
API Gravity	D287	58.0-61.0	61.8*
Distillation % F	D86		
Initial Boiling Point	D86	75-95	93
10% Evap.	D86	120-135	130
50% Evap.	D86	200-230	217
90% Evap.	D86	300-325	310
Maximum	D86	NMT 415	395
10% Slope	D86	NMT 3.2	3.2
Reid Vapor Pressure	D323	8.7-9.2	9.1
Oxidation Stability Minutes	D525	NLT 600	600+
Gum, mg/100 ml (after Heptane Wash)	D381	NMT 4.0	0.4
TMEL grm. lead/gal	D526	NMT 0.05	0.002
Sulfur Weight, %	D1266	NMT 0.10	0.011
Olefin, %	D1319	NMT 10	6.4
Aromatic, %	D1319	NMT 35	20.4
Saturates, %	D1319	Remainder	73.2
Octane Research (Clear)	D2699	95.0-98.5	98.0
Octane Research (3cc TEL/gal)	D2699	NLT 103.0	105.8
Phosphorus, gms./gal.	D3231	NMT 0.005	0.000
Sensitivity (Clear)		7.0-10.5	8.9
Sensitivity (3cc TEL/gal)		NMT 9.0	8.6

DATE: 11-12-75

J. A. GRANT, Manager-Laboratory Services Division

per _____

* WAIVED BY PTD

Table 6. FUEL ANALYSIS

SAMPLE	LEAD (G/GAL)	SULFUR (WT %)	API GRAVITY	REID VAPOR PRES.	DISTILLATION						
					Loss (%)	Residue (%)	IBP (^{o}F)	10% (^{o}F)	50% (^{o}F)	90% (^{o}F)	FBP (^{o}F)
S-1	.005	.032	59.1	8.9	0.9	1.1	92	141	266	328	406
S-2	.004	.032	59.2	9.1	0.8	1.2	90	142	222	314	405
S-3	.004	.033	59.2	8.8	0.5	1.5	90	138	222	316	403
S-4	.004	.034	62.2	9.3	0.5	1.5	104	136	220	326	390
S-5	.009	.033	62.3	9.4	0.5	1.5	108	140	227	342	402
S-6	.009	.033	62.2	9.4	0.7	1.3	89	130	221	326	391
S-7	.007	.035	62.1	9.4	0.5	1.5	88	126	222	330	396

3.2 VEHICLE PREPARATION

Prior to the initiation of mileage accumulation, all of the vehicles, except the Dasher, were tuned to manufacturers specification. The Dasher was tuned by Volkswagen prior to receipt by Olson. The tank fuel was then drained from each vehicle and fueled with the test fuel. An idle emission check was then made. The Dasher's idle emissions were observed to be excessive; CO was 1.4 percent. The Dasher was returned to VW for servicing and two fuel injectors were found to be disconnected. The idle emissions for each vehicle are listed in the data summaries, Section 5.0. No additional maintenance or adjustments were made on the cars after mileage accumulation was initiated.

In order to verify that the vehicle was operating properly prior to mileage accumulation, all vehicles (except the Dasher) were tested using a Clayton Key Mode Test. The results of this check are shown in Table 7.

Table 7. KEY MODE TESTS

VEHICLE	HI CRUISE			LO CRUISE			IDLE "D"	
	Speed (mph)	HC (ppm)	CO (%)	Speed (mph)	HC (ppm)	CO (%)	HC (ppm)	CO (%)
AMC Matador	50	9	.02	35	6	.02	7	.02
Cadillac de Ville	50	15	.02	35	12	.02	12	.02
Buick Skylark	45	10	.03	30	12	.03	8	.02

3.3 MILEAGE ACCUMULATION

Prior to emissions testing, the four vehicles were preconditioned by driving them with the test fuel over a defined road route. The three cars equipped with pelleted

catalysts were preconditoned for 1,000 miles. The VW Dasher, equipped with a monolith catalyst was preconditioned for 500 miles.

The preconditioning road route employed by Olson utilizes public streets and highways located in a nearby rural area. The road route, which is 41.1 miles in length, approximates the modified A.M.A. road route. Table 8 provides details of the route, denoting nominal lap speeds and locations of deceleration and stops.

4.0 EMISSION TESTING PROCEDURES

4.1 DRIVING CYCLES

Upon completion of the mileage accumulation, each of the vehicles was conditioned on the dynamometer using a single repetition of the LA-4 driving cycle. The vehicle was then placed into a controlled temperature soak area for a period of 12 to 20 hours. After the soak period had been completed, the vehicle was tested over the following driving schedule:

- Federal Test Procedure (FTP)
- Sulfate Cycle (1st S-7)
- Sulfate Cycle (2nd S-7)
- Highway Fuel Economy Cycle (FET)
- Sulfate Cycle (3rd S-7)
- Sulfate Cycle (4th S-7)

Upon completion of this driving schedule, the vehicle was again placed in the soak area for another 12- to 20-hour period and then retested using the same driving schedule.

Table 8. SANTIAGO CANYON ROAD ROUTE

LAP	LAP MILES	SPEED (mph)
1	Lap Spd	40
	0.0	0
	0.3	20
	0.7	0
	1.2	20
	1.7	20
	2.0	0
	2.4	20
	2.9	0
	3.3	20
	3.7	0
2	Lap Spd	30
	0.0	0
	0.3	20
	0.7	0
	1.3	20
	1.6	20
	2.1	0
	2.5	20
	3.0	0
	3.2	20
	3.6	0
3	Lap Spd	40
	0.0	0
	0.4	20
	0.8	0
	1.3	20
	1.9	20
	2.4	0
	2.7	20
	3.1	0
	3.4	20
	3.6	0
4	Lap Spd	40
	0.0	0
	0.5	20
	0.8	0
	1.5	20
	1.8	0
	2.3	20
	2.7	20
	3.0	0
	3.2	20
	3.8	0
5	Lap Spd	35
	0.0	0
	0.2	20
	0.8	0
	1.1	20
	1.8	20
	2.3	0
	2.6	20
	3.0	0
	3.4	20
	3.8	0
6A	Lap Spd	30
	0.0	0
	0.3	20
	0.8	0
	1.1	20
	1.9	0
6B	Lap Spd	30
	0.0	0
	0.4	20
	0.6	20
	0.9	0
	1.4	20
	1.9	0
7	Lap Spd	35
	0.0	0
	0.5	20
	0.7	0
	1.0	20
	1.7	20
	2.1	0
	2.4	20
	3.1	0
	3.3	20
	3.8	0
8	Lap Spd	45
	0.0	0
	0.3	20
	0.6	0
	1.0	20
	1.6	20
	1.8	0
	2.4	20
	2.8	0
	3.3	20
	3.6	0
9	Lap Spd	35
	0.0	0
	0.5	20
	0.7	0
	1.0	20
	1.7	20
	2.1	0
	2.4	20
	3.1	0
	3.3	20
	3.8	0
10	Lap Spd	55
	0.0	0
	3.4	0
11	Lap Spd	55
	0.0	0
	2.2	0
	4.2	0

4.2 GASEOUS EMISSIONS MEASUREMENTS

A Clayton Model CE-50 dynamometer equipped with direct-drive inertia flywheels is used for all tests and dynamometer preconditioning. During the course of the test three cooling blowers, Hartzell Propellor Fan Model N 24 DUW, are utilized. Each of these blowers has a flowrate of 5,250 cfm. One is positioned directly in front of the vehicle to cool the radiator and engine. The other two are positioned alongside the car to cool the catalytic converter and fuel system.

Inertia settings were established using actual vehicle weight. Vehicle test weight was defined as shipping weight (as reported in the NADA Used Car Guide) plus a 300-pound allowance for fuel and passenger.

Additionally, the following instrumentation are incorporated in the analytical system for measurement of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_x).

Hydrocarbon Measurement

Two Beckman 400 flame ionization analyzers (HC), using 40 percent H_2-60 percent N_2 fuel. One analyzer with 0 to 100 ppmC and 0 to 300 ppmC ranges; the second for 0 to 1,000 ppmC, 0 to 3,000 ppmC and 0 to 10,000 ppmC ranges.

Carbon Monoxide Measurement

One Bendix 8501-5C nondispersive infrared (NDIR) CO anlayzer with 0 to 100 ppm and 0 to 500 ppm full scale ranges.

One Beckman 315B NDIR CO analyzer with 0 to 0.3 percent, 0 to 3.0 percent, and 0 to 5.0 percent ranges.

Carbon Dioxide Measurement

One Beckman 315B NDIR CO_2 analyzer utilizing the 0 to 4.0 percent, and 0 to 8.0 percent ranges.

Oxide of Nitrogen Measurement

One TECO 10A Chemiluminescence (CL) analyzer with a thermal converter using 0 to 100 ppm, 0 to 250 ppm, 0 to 1,000 ppm and 0 to 2,500 ppm NO_x ranges.

4.3 PARTICULATE/SULFATE EMISSIONS MEASUREMENTS

An air dilution tunnel, shown in Figure 1, was used in series with a conventional Olson-Horiba CVS system. It consists of five separable tubular sections plus an exhaust inlet and sample outlet fitting. The tunnel is constructed of 8-inch diameter stainless steel pipe. Each section is equipped with adjustable feet which allow accurate alignment in assembly. Connection of the various sections and the inlet and sampling ports is accomplished by use of standard Morris couplings. Accurately-machined ends on the tubes ensure smooth transition between the butt joints. Special Teflon liners in the clamps prevent any contact of the diluted exhaust with any material other than stainless steel and Teflon.

Turbulence-inducing vanes are installed in the tubes upstream of the exhaust gas inlet to ensure turbulence and the thorough mixing of the gases.

The exhaust inlet and the sampling ports are welded into the Morris couplings which connect the related sections. This method ensures accurate alignment, allows easy rotation of the exhaust inlet to provide either concurrent or countercurrent flow at the inlet, and provides easy assembly and disassembly for inspection and cleaning of the tunnel.

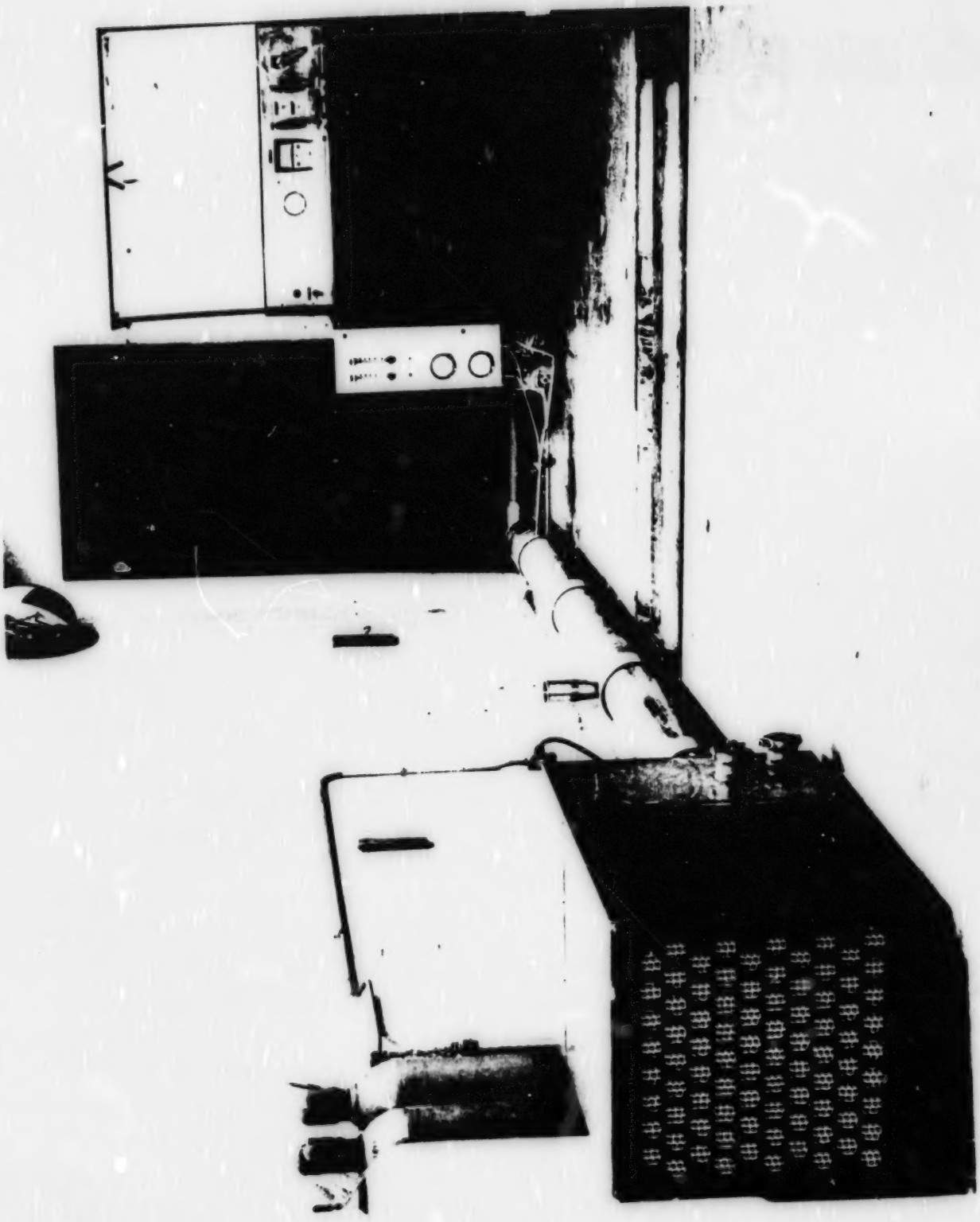

Figure 1. DILUTION TUNNEL

The 3/4-inch stainless steel particulate sampling lines provide for replicate sampling of particulate matter on filters.

The particulate sampling lines feed directly to two 47 mm stainless steel filter holders. Fluoropore[1], Type FA, 1.0μ pore size filters are used as the collection media. Downstream, flow is monitored with two flowmeters, and rotary, oilless, carbon vane pumps are used to draw the air through the filters. The pressure drop across the filter is monitored by Magnehelic vacuum gauges. Details of the particulate sampling system are shown in Figure 2.

An Olson Laboratories' CVS, having a constant flow of 350 cfm, has been connected to the tunnel with all stainless flex tube plumbing. The diluted exhaust from the particulate filters is returned to the CVS at a flanged fitting which replaces the original CVS filter inlet.

Before and after sample collection, gravimetric measurements of the Fluoropore filters were made using a Mettler Model H51 microbalance. This balance has a resolution of 10 μgm which is sufficient to establish accurately the filter weight gains. The microbalance has been installed in a location where a controlled environment and limited access can be maintained.

During the course of the test, the flow through each filter is monitored and the flowrate is recorded. Attempts are made to maintain the flow at a constant rate.

After the weight gain on each filter has been determined, the filters are placed in a container where they are ammoniated. One of the two replicate filters from each test is then selected, and the sulfate particulate extracted. Sulfate determinations are made using the liquid chromatographic barium chloranilate procedure developed by Sigsby and Tejada. For this analysis, Olson utilized an Altex

---

[1]Trademark, Millipore Corp.

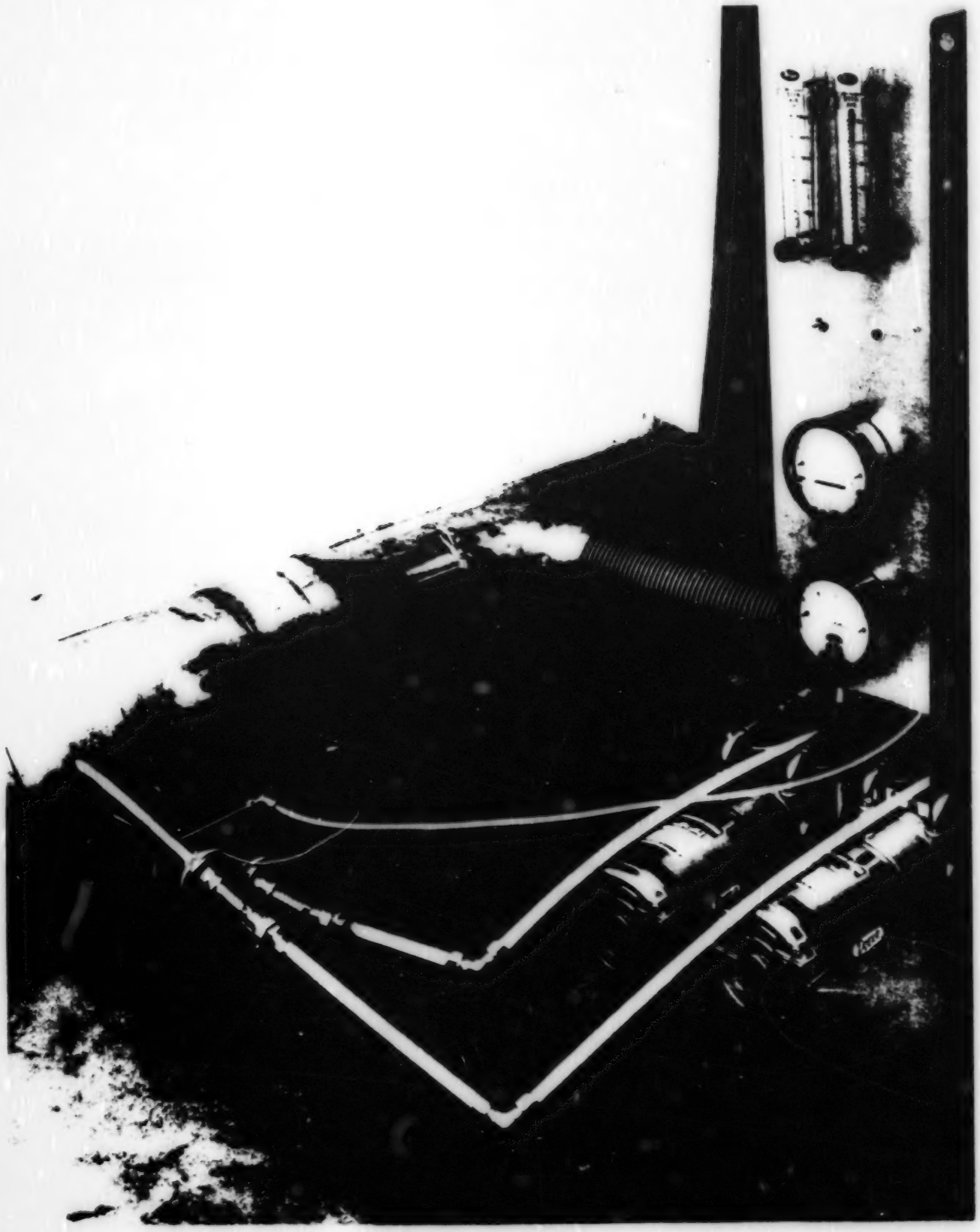

Figure 2. PARTICULATE SAMPLING SYSTEM

Model 300 Liquid Chromatograph equipped with a UV detector monitoring absorption at 313 nm. Daily calibrations of the system are made and periodic checks during each day's run are taken to verify system calibration.

Prior to the analysis of these filters from this test program, Olson had not participated in any laboratory cross correlation or round-robin sulfate tests. However, Olson has regularly submitted duplicate filters to the EPA, Research Triangle Park for analysis as part of the California Consumer-Owned Catalyst-Equipped Vehicle Emissions Study. These analyses have confirmed Olson's procedures and results. Table 9 summarizes the results of these replicate analyses. The particulate mass collected on the two replicate filters of each set varied slightly and the variations in the SO_4 analysis follow this filter-to-filter weight variation.

5.0 TEST RESULTS

The test results for the four cars are shown in Tables 10 through 13. In addition to listing emission rates, the data summaries provide basic vehicle information, fuel data, and fuel economy data.

Two outputs for fuel economy are provided. The first, "mpg (est)" utilizes EPA-developed formulations; the other is based on carbon/hydrogen ratios derived from distillation data.

The Buick Skylark was tested three times. During the first test the fuel system overheated. It was found that the two side cooling systems were directing cooling air across the muffler past the fuel tank. During the second and third test the fans were repositioned to minimize heating of the fuel system. As a result, CO and HC emissions during the hot-start cycles, the S-7s and FET were lower during the second and third test as compared to the first.

Table 9. COMPARATIVE SO_4 ANALYSIS

VEHICLE NUMBER	TEST I.D.	OLSON ANALYSIS (mg)	EPA ANALYSIS (mg)
010	FTP	152	141
	1st S-7	202	183
	2nd S-7	244	292
	FET	375	340
	3rd S-7	625	575
	4th S-&	694	650
	FTP Retest	159	153
020	FTP	440	240
	1st S-7	375	377
	2nd S-7	124	113
	FET	169	148
	3rd S-7	69	60
	4th S-7	72	64
030	FTP	1820	1866
	1st S-7	3688	3685
	2nd S-7	2908	2716
	FET	2750	2735
	3rd S-7	3075	3119
	4th S-7	3300	3135

Table 10
SPECIAL TEST RESULTS

VEHICLE NO. 9001 VEH. MFG. S YR- 76 MAKE- DASHER SERIAL NO. - 326204523
LIC. NO. DP11976 CYL- 4 CID- 097 BBL-FI ENG. FAM.- CAT. MFG.-
A/C -YES P/S-NO P/B-NO TRANS-AUTO INERTIA- 2500 AHP- 10.3

FUEL MEASUREMENTS:

TEST NO.	DATE	BRAND	LEAD	SULFUR	APIGR	RVP	LOSS	RESIDUE	IBP	50	FBP
1	02/16/76	14.	.005	.032	59.1	8.9	0.9	1.1	92.	226.	406.
2	02/17/76	14.	.004	.032	59.2	9.1	0.8	1.2	90.	222.	405.
3											

IDLE ENGINE PARAMETERS:

TEST NO.	DATE	DWELL	TIMING	RPM	CO%	HC(PPM)
STICKER	02/16/76					
1 BEFORE	02/16/76				0.02	0.
1 AFTER	02/16/76				0.0	0.
2 BEFORE	02/17/76				0.02	0.
2 AFTER	02/17/76				0.0	0.
3 BEFORE						
3 AFTER						

COMMENTS:

TEST NO.	
1	NO AFT TEST PARA
2	NO AFTER TEST
3	

Table 10 (Continued)
MASS EMISSION TEST RESULTS

VEHICLE NO. 9001 MAKE - DASHER CYL - 4 CID - 097

	TEST NO.	HC G/M	CO G/M	CO2 G/M	NOXC G/M	FUEL ECONOMY (MPG) (EST)	FUEL ECONOMY (MPG) (ACT)	SO2 MG/M	SO4 MG/M AVE	PART MG/M AVE	SULFATE /PARTIC RATIO	--- SULFUR BALANCE --- PCT SO2 CONVTD	PCT SO4 CONVTD	PCT S SUM	ODOM.
1975 FTP	1	0.28	4.43	414.1	1.82	21.04	24.04	*****	0.58	5.87	0.10	*****	0.45	0.45	1358
	2	0.24	3.94	415.3	2.23	21.02	24.01	*****	0.43	2.14	0.20	*****	0.33	0.33	1435
	3														
1ST S-7	1	0.08	0.61	341.8	2.18	25.87	29.58	*****	3.69	6.53	0.56	*****	3.54	3.54	
	2	0.09	0.75	331.3	2.40	26.68	30.48	*****	1.52	4.61	0.33	*****	1.51	1.51	
	3														
2ND S-7	1	0.08	0.63	342.2	2.22	25.84	29.54	*****	3.57	5.77	0.62	*****	3.43	3.43	
	2	0.08	0.58	331.6	2.25	26.67	30.47	*****	1.66	3.70	0.45	*****	1.65	1.65	
	3														
FET	1	0.06	0.11	313.3	2.16	28.29	32.34	*****	4.58	7.26	0.63	*****	4.81	4.81	
	2	0.06	0.16	308.8	2.10	28.70	32.79	*****	2.96	5.04	0.59	*****	3.16	3.16	
	3														
3RD S-7	1	0.08	0.70	331.3	2.11	26.68	30.50	*****	2.71	5.46	0.50	*****	2.68	2.68	
	2	0.07	0.46	320.5	2.15	27.61	31.54	*****	1.65	2.46	0.67	*****	1.69	1.69	
	3														
4TH S-7	1	0.08	0.51	336.1	2.26	26.32	30.09	*****	3.23	5.15	0.63	*****	3.15	3.15	
	2	0.07	0.43	317.2	2.10	27.90	31.88	*****	1.72	3.22	0.53	*****	1.78	1.78	
	3														

Table II
SPECIAL TEST RESULTS

VEHICLE NO. 9002 VEH. MFG. 4 YR- 76 MAKE- MATADOR SERIAL NO. - A6A857H21733
LIC. NO. 381 NRR CYL- 8 CID- 304 BBL- 2 ENG. FAM.- CAT. MFG.-
A/C -YES P/S-YES P/B-YES TRANS-AUTO INERTIA- 4000 AHP- 13.2

FUEL MEASUREMENTS:

TEST NO.	DATE	BRAND	LEAD	SULFUR	APIGR	RVP	LOSS	RESIDUE	IBP	50	FBP
1	02/18/76	14.	.004	.032	59.2	9.1	0.8	1.2	90.	222.	405.
2	02/19/76	14.	.004	.033	59.2	8.8	0.5	1.5	90.	222.	403.
3											

IDLE ENGINE PARAMETERS:

TEST NO.	DATE	DWELL	TIMING	RPM	COE	HC(PPM)
STICKER	02/18/76		5BT	800		
1 BEFORE	02/18/76		5BT	890	0.02	10.
1 AFTER	02/18/76				0.0	0.
2 BEFORE	02/19/76		5BT	890	0.02	10.
2 AFTER	02/19/76		5BT	775	0.03	15.
3 BEFORE						
3 AFTER						

COMMENTS:

TEST NO.	
1	NO AFTER TEST
2	
3	

Table 11 (Continued)
MASS EMISSION TEST RESULTS

VEHICLE NO. 9002 MAKE - MATADOR CYL - 8 CID - 304

	TEST NO.	HC G/M	CO G/M	CO2 G/M	NOXC G/M	FUEL ECONOMY (MPG) (EST)	FUEL ECONOMY (MPG) (ACT)	SO2 MG/M	SO4 MG/M AVE	PART MG/M AVE	SULFATE /PARTIC RATIO	--- SULFUR BALANCE --- PCT SO2 CONVTD	PCT SO4 CONVTD	PCT S SUM	ODOM.
1975 FTP	1	0.42	6.83	751.4	2.15	11.63	13.28	*****	0.37	5.75	0.06	*****	0.16	0.16	2426
	2	0.46	7.20	757.4	2.17	11.52	13.16	*****	0.33	3.90	0.09	*****	0.14	0.14	2502
	3														
1ST S-7	1	0.08	1.09	564.5	3.14	15.67	17.90	*****	0.37	1.15	0.32	*****	0.21	0.21	
	2	0.12	4.14	562.6	2.87	15.58	17.81	*****	0.23	2.06	0.11	*****	0.13	0.13	
	3														
2ND S-7	1	0.07	0.74	554.3	3.18	15.97	18.25	*****	0.35	1.77	0.20	*****	0.21	0.21	
	2	0.07	1.00	553.9	2.99	15.97	18.25	*****	0.32	1.53	0.21	*****	0.18	0.18	
	3														
FET	1	0.05	0.21	499.4	3.53	17.76	20.29	*****	0.64	0.72	0.89	*****	0.42	0.42	
	2	0.05	0.38	496.5	3.33	17.85	20.39	*****	0.77	2.45	0.32	*****	0.50	0.50	
	3														
3RD S-7	1	0.07	1.54	553.4	3.18	15.96	18.24	*****	0.28	1.76	0.16	*****	0.16	0.16	
	2	0.11	3.91	550.0	2.87	15.95	18.22	*****	0.37	1.84	0.20	*****	0.21	0.21	
	3														
4TH S-7	1	0.07	0.93	546.3	3.10	16.20	18.51	*****	0.48	0.77	0.62	*****	0.29	0.29	
	2	0.07	1.61	552.7	3.14	15.98	18.26	*****	0.40	1.07	0.37	*****	0.23	0.23	
	3														

Table 12
SPECIAL TEST RESULTS

VEHICLE NO. 9003 VEH. MFG. 1 YR- 76 MAKE- CAD DVLL SERIAL NO. - 6D47S6Q12695
LIC. NO. 869 MXS CYL- 8 CID- 500 BBL- 4 ENG. FAM.- 6LV 4 CAT. MFG.-
A/C - YES P/S- YES P/B- YES TRANS- AUTO INERTIA- 5500 AHP- 15.3

FUEL MEASUREMENTS:

TEST NO.	DATE	BRAND	LEAD	SULFUR	APIGR	RVP	LOSS	RESIDUE	IBP	50	FBP
1	02/25/76	0.	.004	.034	62.2	9.3	0.5	1.5	104.	220.	390.
2	02/26/76	0.	.009	.033	62.3	9.4	0.5	1.5	108.	227.	402.
3											

IDLE ENGINE PARAMETERS:

TEST NO.	DATE	DWELL	TIMING	RPM	CO%	HC(PPM)
STICKER	02/25/76		6BT	600		
1 BEFORE	02/25/76		8BT	575	0.07	25.
1 AFTER	02/25/76				0.0	0.
2 BEFORE	02/26/76		8BT	575	0.07	25.
2 AFTER	02/26/76		7BT	575	0.03	15.
3 BEFORE						
3 AFTER						

COMMENTS:

TEST NO.	
1	HOT TRAN CRNK TM
2	
3	

Table 12 (Continued)
MASS EMISSION TEST RESULTS

VEHICLE NO. 9003 MAKE - CAD DVLL CYL - 8 CID - 500

	TEST NO.	HC G/M	CO G/M	CO2 G/M	NOXC G/M	FUEL ECONOMY (MPG) (EST)	FUEL ECONOMY (MPG) (ACT)	SO2 MG/M	SO4 MG/M AVE	PART MG/M AVE	SULFATE /PARTIC RATIO	--- SULFUR BALANCE --- PCT SO2 CONVTD	PCT SO4 CONVTD	PCT S SUM	ODOM.
1975 FTP	1	0.56	6.34	840.4	1.84	10.42	11.71	*****	1.08	5.49	0.20	*****	0.40	0.40	9025
	2	0.48	6.59	844.3	1.80	10.37	11.65	*****	0.61	4.45	0.14	*****	0.23	0.23	9104
	3														
1ST S-7	1	0.13	0.76	653.2	1.31	13.55	15.24	*****	3.65	8.21	0.44	*****	1.76	1.76	
	2	0.18	0.59	669.3	1.66	13.23	14.87	*****	4.70	9.13	0.51	*****	2.27	2.27	
	3														
2ND S-7	1	0.12	0.40	639.9	1.62	13.85	15.57	*****	4.02	7.06	0.57	*****	1.98	1.98	
	2	0.12	0.47	658.4	1.69	13.46	15.12	*****	5.72	10.12	0.57	*****	2.82	2.82	
	3														
FET	1	0.09	0.51	604.6	1.55	14.65	16.47	*****	10.00	17.82	0.56	*****	5.21	5.21	
	2	0.09	0.09	613.6	1.64	14.46	16.24	*****	11.69	18.84	0.62	*****	6.18	6.18	
	3														
3RD S-7	1	0.13	1.22	641.1	1.62	13.80	15.51	*****	3.04	7.53	0.40	*****	1.49	1.49	
	2	0.11	0.10	658.7	1.74	13.46	15.13	*****	9.54	15.67	0.61	*****	4.70	4.70	
	3														
4TH S-7	1	0.13	1.03	648.8	1.41	13.64	15.33	*****	6.19	9.98	0.62	*****	3.00	3.00	
	2	0.11	0.06	661.1	1.75	13.42	15.08	*****	19.73	34.84	0.57	*****	9.69	9.69	
	3														

Table 13
SPECIAL TEST RESULTS

VEHICLE NO. 9004 VEH. MFG. 1 YR- 76 MAKE- SKYLARK SERIAL NO. - 4B27C6L10081
LIC. NO. 096 PEB CYL- 6 CID- 231 BBL- 2 ENG. FAM.- BA 41E2Z CAT. MFG.-
A/C - YES P/S-YES P/B-YES TRANS-AUTO INERTIA- 3500 AHP- 12.3

FUEL MEASUREMENTS:

TEST NO.	DATE	BRAND	LEAD	SULFUR	APIGR	RVP	LOSS	RESIDUE	IBP	50	FBP
1	03/08/76	0.	.009	.033	62.3	9.4	0.5	1.5	108.	227.	402.
2	03/09/76	0.	.009	.033	62.2	9.4	0.7	1.3	89.	221.	391.
3	03/10/76	0.	.007	.035	62.1	9.4	0.5	1.5	88.	222.	396.

IDLE ENGINE PARAMETERS:

TEST NO.	DATE	DWELL	TIMING	RPM	CO%	HC(PPM)
STICKER	03/08/76		12BT	600		
1 BEFORE	03/08/76		8BT	750	0.03	50.
1 AFTER	03/08/76				0.0	0.
2 BEFORE	03/09/76		8BT	750	0.03	50.
2 AFTER	03/09/76				0.0	0.
3 BEFORE	03/10/76		8BT	750	0.03	50.
3 AFTER	03/10/76		12BT	700	0.70	120.

COMMENTS:

TEST NO.	
1	FUEL SYST OVRHET
2	FANS MOVED
3	

Table 13 (Continued)
MASS EMISSION TEST RESULTS

VEHICLE NO. 9004 MAKE - SKYLARK CYL - 6 CID - 231

	TEST NO.	HC G/M	CO G/M	CO2 G/M	NOXC G/M	FUEL ECONOMY (MPG) (EST)	FUEL ECONOMY (MPG) (ACT)	SO2 MG/M	SO4 MG/M AVE	PART MG/M AVE	SULFATE /PARTIC RATIO	--- SULFUR BALANCE --- PCT SO2 CONVTD	PCT SO4 CONVTD	PCT S SUM	ODOM.
1975 FTP	1	0.85	14.55	532.0	1.08	15.92	17.88	*****	0.15	1.86	0.08	*****	0.09	0.09	2229
	2	0.99	23.31	549.6	1.05	15.06	16.92	*****	0.13	4.04	0.03	*****	0.07	0.07	2312
	3	0.75	14.37	547.6	1.10	15.50	17.43	*****	0.20	1.11	0.18	*****	0.11	0.11	2390
1ST S-7	1	0.35	9.09	396.3	0.89	21.56	24.22	*****	0.23	2.52	0.09	*****	0.18	0.18	
	2	0.22	5.20	421.5	1.32	20.62	23.18	*****	0.30	0.99	0.31	*****	0.23	0.23	
	3	0.36	8.19	416.6	1.30	20.61	23.18	*****	0.14	1.22	0.11	*****	0.10	0.10	
2ND S-7	1	0.67	20.14	366.1	0.57	22.19	24.92	*****	0.20	1.14	0.17	*****	0.16	0.16	
	2	0.22	5.28	409.9	1.33	21.19	23.82	*****	0.23	1.14	0.20	*****	0.18	0.18	
	3	0.26	7.41	416.4	1.30	20.69	23.28	*****	0.09	0.15	0.60	*****	0.07	0.07	
FET	1	0.85	23.73	336.6	0.59	23.57	26.45	*****	0.12	0.41	0.30	*****	0.11	0.11	
	2	0.11	2.26	371.2	1.13	23.66	26.60	*****	0.16	1.42	0.11	*****	0.14	0.14	
	3	0.11	1.57	378.4	1.27	23.28	26.19	*****	0.06	0.20	0.30	*****	0.05	0.05	
3RD S-7	1	0.95	28.45	358.2	0.59	21.86	24.54	*****	0.14	0.23	0.60	*****	0.11	0.11	
	2	0.24	6.77	408.3	1.28	21.15	23.77	*****	0.09	0.53	0.17	*****	0.07	0.07	
	3	0.25	7.97	408.9	1.27	21.02	23.64	*****	0.08	1.22	0.06	*****	0.06	0.06	
4TH S-7	1	0.87	26.45	366.4	0.51	21.61	24.26	*****	0.14	0.0	*****	*****	0.11	0.11	
	2	0.38	11.73	394.7	1.14	21.42	24.08	*****	0.11	1.67	0.06	*****	0.08	0.08	
	3	0.22	6.90	408.5	1.31	21.13	23.77	*****	0.09	0.84	0.11	*****	0.07	0.07	

As shown in the test results, the vehicles tested exhibited lower sulfate emissions than other vehicles of this type tested in the baseline program. The reasons for this are not known. However, the emission levels from each vehicle were consistent from test to test and, in the two cases where comparisons could be made, these results agreed well with similar vehicles which Olson has tested in other programs. These comparative results are shown in Table 14.

Table 14. COMPARATIVE SO_4 RESULTS

VEHICLE	BASELINE STUDY			CALIFORNIA CONSUMER STUDY		
	FTP (mg/mi)	Avg S-7 (mg/mi)	HFET (mg/mi)	FTP (mg/mi)	Avg S-7 (mg/mi)	HFET (mg/mi)
Buick Skylark	0.16	0.15	0.11	0.46	0.18	0.16
Cadillac	0.85	7.07	10.85	0.26	13.24	4.09